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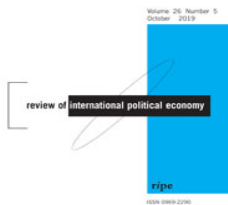
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Understanding technological change in global finance through infrastructures

Introduction to Review of International Political Economy Special Issue 'The Changing Technological Infrastructures of Global Finance'

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ABSTRACT

Amid escalating claims about the promises and perils of emergent financial technologies (fintech), critical investigation of the extent to which specific technological changes in global finance are truly 'disruptive' is sorely needed. Yet, IPE has engaged little with the growing focus on fintech in popular and regulatory debates, as well as in Social Studies of Finance (SSF). This article and accompanying special issue foreground 'infrastructures' as a heuristic for injecting nuance into debates on the emergence, limits and implications of technological changes in global finance while bringing IPE into conversation with perspectives on fintech in cognate literatures. Building on insights developed in Science and Technology Studies (STS), we argue that tracing the ways in which infrastructures enabling financial markets to operate are assembled out of multiple old and new socio-technical devices offers productive avenues for addressing key questions arising from several entanglements underpinning technological change. The findings of contributions to this special issue are linked to two key themes in debates on the impacts of technological change: financial inclusion and financial stability. Further avenues are proposed for examining the infrastructures in which technological change occurs in global finance and beyond, while fostering on-going dialogues between IPE, STS and SSF.

KEYWORDS

Finance; technology; innovation; infrastructure; governance; financial inclusion; financialization

Machines are taking over Wall Street. Artificial intelligence, mathematical models, and supercomputers have replaced human intelligence, human deliberation, and human execution. The modern financial industry is becoming faster, larger, more complex, more global, more interconnected, and less human. (Lin, 2014, p. 568)

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The increased use of digital technologies by [micro, small and medium enterprises (MSMEs)] and their customers is generating a wealth of new data that can be used to understand the MSME market, assess creditworthiness, and manage risk more effectively. A growing number of financial technology companies, known as 'fintechs', are developing innovative tools to do precisely this. As a result, traditional financial institutions are faced with both a unique challenge and an enormous opportunity. (Hoder, Wagner, Sguerra, & Bertol, 2016, p. 7)

These passages both convey an increasingly widespread sense that global finance is being fundamentally transformed by technological change. Discussions of financial activities enabled by digital technologies—including artificial intelligence, big data, cryptocurrencies, high-frequency trading (HFT), peer-to-peer lending—tend to be dominated by extremes. Advocates of so-called 'digital disruption' celebrate the potential for technological change to contribute to more inclusive, efficient, and consumer-friendly financial practices. Applications of new technologies for 'financial inclusion' are particularly prominent in this respect. Critics, meanwhile, decry how new technologies render the financial sector increasingly unstable and ungovernable (e.g. Harris, 2011; Lin, 2014; Thompson, 2017) while enabling pervasive surveillance of everyday life (e.g. Fourcade & Healy, 2017; Gabor & Brooks, 2017). One way or another, there is a growing sense that technological change is radically altering the way that finance works.

Yet, such hopes and concerns surrounding technological change in global finance are far from new. Readers will likely recognize some echoes of debates in the 1990s over the role of ICTs in facilitating the 'globalization' of finance. International Political Economy (IPE) scholarship made significant contributions to these earlier debates with critical attention to the roles of state power in shaping patterns of technological change and their consequences, as well as to understanding the connections between technological change and wider shifts in patterns of power and accumulation in the global political economy (e.g. Cerny, 1994a; Gill, 1995; Goodman & Pauly, 1993; Helleiner, 1994; Strange, 1990). Importantly, perhaps the core insight from these earlier debates—that technology was not an 'external' driver of social, political, and economic change, but rather itself powerfully shaped by political struggles, forms of governance, and accumulation strategies—remains pertinent to contemporary debates.

IPE scholarship, however, has mostly gone missing in present day debates over new financial technologies ('fintech'). Keyword searches of articles published in this journal, in *International Organization*, *International Studies Quarterly*, and *New Political Economy* as of May 2019 for 'fintech', 'artificial intelligence', 'big data', 'cryptocurrency', and 'high frequency trading' yielded exactly five results (Campbell-Verduyn, Goguen, & Porter, 2017; Gabor & Brooks, 2017; Gruin & Knaack 2019, Kremers & Brassett, 2017; Thompson 2017). Some IPE scholars *have* engaged with debates about technological change in finance, but it is striking that their work on the subject is more likely to be found outside what might be considered core IPE journals (e.g. Aitken, 2017; Amoore, 2011; Clarke & Tooker, 2018; Langley & Leyshon, 2017).

This gap might be attributed in part to the research agendas and methodological commitments that have dominated the IPE of finance in the last decade. The 'meat and potatoes' of recent scholarship in IPE journals has been identified as a pair of linked clusters of research around (1) global economic governance and (2)

international organizations focused on ‘exploring ideas, interests, and institutions through cases’ (Seabrooke & Young, 2017, pp. 309–310). There have been, amongst other things, important investigations of regulatory responses to the 2007/08 global financial crisis (e.g. Helleiner, Pagliari, & Spagna, 2018; Porter 2014); interlinked institutional and ideational dimensions of financial and economic governance (e.g. Underhill, 2015; Widmaier, 2016); the changing operations of key institutions, notably the International Monetary Fund, World Bank and G20 (e.g. Clift, 2018; Grabel, 2018); and the production and circulation of expertise (e.g. Ban, Seabrooke, & Freitas, 2016; Tsingou, 2015). However, the relative absence of contemporary debates concerning technological change in finance suggests to us that recent IPE scholarship is overlooking important actual or potential structural shifts in the global financial system. The absence of IPE perspectives on emergent technologies is all the more problematic because these are areas of increasing concern to civil society organizations, financial service firms, regulators, and the public at large.

The extent to which this core focus on ‘ideas, interests, and institutions’ is responsible for the absence of IPE attention to technological change in finance is underlined by the growing debates on novel applications of digital technologies in global finance in the interdisciplinary literature on Social Studies of Finance (SSF). SSF draws on a longstanding tradition of critical engagement with the ‘microstructures’ underpinning global finance (Knorr Cetina & Bruegger, 2002) primarily by anthropologists, geographers, and sociologists, often influenced by Science and Technology Studies (STS). SSF has been dominated by close, granular, detailed studies of the making of the mundane objects and technical devices underpinning financial markets. SSF show that in global finance both social and material ‘equipment matters’ (MacKenzie, 2009, p. 4). Critically, this level of attention to ‘market devices’ (Erturk, Froud, Johal, Leaver, & Williams, 2013; Muniesa, Millo, & Callon, 2007), microstructures, and ‘opening black boxes’ (MacKenzie 2005) has left SSF well positioned to provide insightful analyses of emergent technologies that IPE studies of global finance have largely missed (e.g. Beverungen & Lange, 2018; Hayes, 2019; MacKenzie, 2017, 2018; Swartz, 2018).

Yet, SSF nevertheless have their own shortcomings. Not least, fine-grained analyses of technical systems can lose sight of larger questions of power, governance, and accumulation, even resulting in some cases in the uncritical reproduction of market participants’ assumptions about how financial markets work (see Christophers, 2014; Fine, 2003). Thus, while offering productive pathways for studying technological changes in global finance, SSF could also benefit from more engagement with traditional IPE questions of authority, governance and power. Indeed, several other scholars have noted such scope for productive interdisciplinary engagements (Coombs, 2016, 2018; Cooper & Konings, 2015; Langley, 2008, pp. 6–7; McKeen-Edwards & Porter, 2013; Paudyn, 2013, p. 794; Samman, Coombs, & Cameron, 2015, pp. 3–4).

A key obstacle to such engagements, we think, is that technologies often do not neatly fall into the categories through which IPE have operationalized global finance in recent years. Technology, as we argue further below, occupies a liminal space between ‘ideas’ and ‘material’ factors. Technologies are both profoundly linked to ideas and knowledges, but also ‘material’. Indeed, they are ‘material’ in a literal sense—they are physical objects—not always captured by the focus on interests, class relations, or coercive power which IPE scholars usually imply by

referring to the 'material'. Similarly, technologies (particularly ICTs) are often at once 'global' or 'international' as well as 'local' and 'national'. They can provide the key connections between geographically dispersed locations that enable, and disable, financial activities to occur across borders. These kinds of linkages, however, fit awkwardly into the focus on multilateral institutions through which the 'international' has often been operationalized in IPE in recent years—except, notably, where the 'plumbing' of financial systems is itself the object of regulatory debates (e.g. Jeffs, 2008). In short, technologies bundle and blur the scales of activity and foundational categories underlying much work in contemporary IPE. Accordingly, both in bridging IPE and SSF, and (more importantly) in understanding the drivers and implications of technological change in global finance, there is a need for some degree of conceptual innovation.

Our main contention in this article and the accompanying special issue more broadly is that 'infrastructures' offer productive avenues for (1) on-going dialogues between SSF and IPE, as well as (2) injecting nuance and caution into on-going debates regarding the emergence and implications of technological changes in global finance. We draw on STS perspectives where infrastructures are understood as combinations of emerging and existing social and technical systems through which basic but crucial enabling functions are carried out, but that tend to be taken for granted and assumed (see Bowker & Star, 1996; Edwards, 2003; Star, 1999). In global finance, such infrastructures include both the new and established systems through which payments are settled, risks are assessed, and prices agreed. Examining infrastructures is useful for two reasons. First, both optimistic and pessimistic arguments about the impacts of new technologies in global finance often boil down to claims about how fintech might change the way backgrounded functions (payment, pricing, risk assessment) are carried out. In examining how seemingly novel technologies fit into wider socio-technical systems we can better comprehend patterns of change. Second, there is considerable potential for infrastructures to invite questions of power and politics back in to what can risk becoming merely 'technical' debates about change in global finance. Notions of 'infrastructural power' (Braun, 2018; Cerny, 1994b; Mann, 1984), for instance, have previously been used to invoke the kinds of power enabled by control over the backgrounded features of economic life exercised by financial markets. Rather than taking technological change as an external force acting on the financial sector, thinking in terms of 'infrastructures' helps examine how the emergence and adoption of new technologies are driven by internal patterns of political economy (e.g. accumulation, governance), and the limits to the capacity of 'disruption' and 'innovation' to fundamentally remake finance.

The remainder of this article proceeds in three steps. First, we elaborate a conception of infrastructures and show how it can usefully illuminate three sets of entanglements underlying technological change in global finance. Second, we summarize the contributions to this special issue, linking their findings to two key themes in debates on the impacts of technological change: financial inclusion and financial stability. Finally, we conclude with brief reflections on directions for further research.

Understanding change through infrastructures

What exactly do we mean by 'infrastructures'? In colloquial use, the term normally refers to large-scale technical systems (transport networks, sewers, electrical grids).

Here, however, we follow Bowker and Star (1996) and other STS scholars in referring less to specific systems and more to the ways in which the socio-technical systems enabling basic, often backgrounded functions are assembled out of multiple old and new devices (cf. Edwards, 2003; Star, 1999). ‘Infrastructures’ understood in this sense are as much a heuristic device as a specific set of objects, highlighting five key characteristics:

- *Facilitation*: Infrastructures don’t *do* anything, per se. Rather, they make other activities possible.
- *Openness*: Infrastructures facilitate in large part through the routinization and standardization of core processes, they ‘do not have to be reinvented each time or assembled for each task’ (Star, 1999: 381). They are, as a result, open to use by a greater or lesser range of actors, not just the people immediately responsible for ‘assembling’ them.
- *Durability*: They persist over time, and constitute an ‘installed base’ (Star 1999, p. 381) into which new devices need to be integrated.
- *Centrality*: Infrastructures shape the way core functions are undertaken.
- *Obscurity*: Infrastructures involve large technical systems operating largely in the background, and can be ‘black boxed’ by their users.

Crucially, infrastructures in this sense are understood as ‘a contextualized “relation” rather than a “thing”’, with a key task for analysis being to ‘emphasize the situated practical work of developing and using infrastructures’ (Karasti, Millerand, Hine, & Bowker, 2016, p. 4). In global finance, as noted above, ‘infrastructures’ include the new and established systems enabling various actors to make payments, set prices, and assess risks. The infrastructures enabling such functions are made up of bundles of *both* physical, non-human objects (fiber-optic cables, computers, servers, payment cards) *as well as* a range of human practices including the techniques and standards involved in developing and maintaining software packages, statistical models, and automated algorithms. As evolving socio-technical systems, infrastructures are *combinations* of the human and non-human elements enabling key functions in global finance.

Understanding technological change by foregrounding the ways in which the systems through which basic functions are carried out provides useful leverage in understanding recent developments in global finance. Specifically, infrastructures illuminate three sets of questions arising from analyzing entanglements that underpin technological change. In the following three sub-sections we show how infrastructures help to navigate the material and ideational, the micro and macro, as well as the political and technical underpinnings of technological change in manners that draw on what we regard as complementarities between SSF and IPE. We ground each discussion briefly in debates around the development and expansion of high frequency trading (HFT) infrastructures, which in many ways are archetypical of recent technological developments that have had systemic impacts on global finance.

Bridging the material and ideational

STS-inflected notions of infrastructures draw attention to the material manifestations of ideas in human practices and non-human objects. A focus on

infrastructures thus implies an emphasis on the ways in which technical systems are socially *constructed*. However, unlike the emphasis on the constitutive power of ideas underlying most constructivist scholarship in IPE (Abdelal, Blyth, & Parsons, 2010), this approach involves a rejection of any binary between 'ideas' and the mundane materialities to which they refer, through which they are enacted, and within which ideas are contained.

This understanding of infrastructures, in short, follows much STS scholarship in placing an emphasis on the material manifestations of abstract ideas in human practices and non-human objects. Rather than focusing on the causal force of 'ideas' in and of themselves, foregrounding infrastructures helps bridge what tends to be a stress on *either* the material or the ideational (Branch, 2018, pp. 105–106). This builds on STS insights into how social relations are made durable by their embodiment in the material world, through processes that are rarely straightforward (see Latour, 2005). While some recent IPE studies of finance have drawn on ideas from STS scholars, particularly Callon (1998) and McKenzie (2006), in insightful analyses that have considered the performative nature of finance (Braun, 2016; Kranke & Yarrow, 2018; Lockwood, 2015; Stellinga & Mügge, 2017), the roles of mundane technical devices and material objects in shaping the day-to-day operations of financial markets have tended to be overlooked. In stressing how ideas and materials often become intertwined in unexpected manners, a focus on 'infrastructures' helps ground IPE analysis of change in global finance within specific sets of ideas that are intrinsically related to the socio-technical objects and practices underpinning financial markets.

The inseparability of the material and ideational is useful for studying technological change in global finance for two reasons. First, it helps combat the tendency to treat financial systems as abstract, dematerialized realms of activity. A focus on the materiality of infrastructures stresses that the increasingly digital nature of global finance remains grounded in *physical* objects and practices. For instance, the ability to enact financial trades at speeds of up to a millisecond relies on energy-intensive servers housed in air-conditioned warehouses, or 'co-located' within exchanges that are themselves connected together through fiber optic cables, many of which were purposely-built to enable the wider use of HFT strategies (see MacKenzie, 2018; MacKenzie, Beunza, Millo, & Pardo-Guerra, 2012). In other words, it takes considerable energy, investment, and reconfigurations of physical space (both locally and across considerable distances) to make HFT possible. Quite apart from the impact of HFT on financial stability, attention to its material entanglements can allow IPE scholars to question the social desirability of using resources in such ways, or point to new vulnerabilities created in such processes of change.

Second, and related, taking seriously the continually evolving connections between the material and ideational directs attention to the *limits* of technological change in critical ways. New technologies scarcely ever replace complex socio-technical systems wholesale. Instead, as Star (1999, p. 382) argues, infrastructural change continually 'wrestles with the inertia of the installed base and inherits strengths and limitations from that base'. Overhauls of infrastructures that are 'big, layered, and complex' tend to require 'time and negotiation, and adjustment with other aspects of the systems that are involved' (Star, 1999, p. 382). Indeed, a number of STS scholars eschew the notion that infrastructures are 'built' in favor of

‘transitory verbs’ like ‘infrastructuring’ (Edwards, Bowker, Jackson, & Williams, 2009, pp. 369–370). In HFT, both trading algorithms and the physical infrastructures they work through have had to be designed to interact with the existing infrastructures of electronic trading on stock exchanges. HFT depends on the presence of computerized and highly liquid markets. As noted, computer servers need to be located as close to possible to those of conventional exchanges. HFT companies thus tend to cluster around major trading platforms in London, New York, Chicago, and Singapore (Garvey & Wu, 2010; Goldstein, Kumar, & Graves, 2014). Paying attention to the ways in which new technologies are plugged into the ‘installed base’ of human actors, non-human objects, and the connections between them can provide a more nuanced understanding of how infrastructures are often limited in terms of the kinds of activities they can (and cannot) facilitate. As Star notes, ‘For the person in the wheelchair, the stairs and door jamb in front of a building are not seamless subtenders of use, but barriers’ (1999, p. 380). A key premise here is that the enactment and embodiment of ideas about finance can be inherently limited by a reliance on the very same non-human objects that enable (financial) activities, in ways that are not always anticipated (Latour, 2005). The development of HFT, here again, has continuously depended on the competitive and contested construction of trading algorithms by market participants. These have proven systematically capable of processing some kinds of information and not others, with significant consequences in terms of vulnerability to sudden market volatilities (Lenglet, 2011).

The overarching point here is that STS-inflected notions of infrastructures stressing the interconnections between the material and ideational, as well as the human and the non-human allow for technological change in global finance to be understood in more nuanced manners than bifurcated debates tend to suggest. Financial infrastructures bundle together an array of models, standards, techniques for valuation, and algorithms into physical objects—often with unexpected results. These ‘virtual’ devices are both empowered and profoundly limited by the ways in which they must be enacted through material objects, places, and practices that are often connected together in fragile manners within and across borders.

Bridging the micro and macro

Studying technological change through infrastructures also enables more nuanced understanding of the scales and spatialities of technological change. STS-inflected understandings of infrastructure build on distinctive understandings of space and scale that blur micro and macro levels of activity, which could be described as ‘topological’ or ‘relational’. The concept of infrastructures rests on an understanding of space emphasizing modalities of connection through which spatial and temporal distances are unevenly mediated rather than territories or surfaces (Allen, 2011). This usefully corrects a tendency in IPE to assume, rather than interrogate, the ‘global’ or ‘international’ character of financial markets and their governance.

The making of ‘global’ financial systems requires infrastructures capable of stitching together and circulating myriad ‘local’ or ‘micro’ objects and routines across a variety of sites (see Latour, 2005, p. 176). Investigating infrastructures provides a more nuanced sense of the ways in which global finance facilitates connections between some kinds of places and some kinds of activities more easily than

others. HFT again serves as a useful example here. While fiber-optic cables tie server farms in New York and Chicago closer together, the algorithms through which HFT works simultaneously increase the practical distance between trading operations and the real economic activities on which securities markets ultimately rest (Coeckelbergh, 2016). These forms of unevenness can also have critical consequences for the actual diffusion of new technologies. HFT accounts for a highly variable proportion of trades on different exchanges, from well over half of trading on a number of London-based digital platforms (Chi-X, Turquoise, and BATS) to 20 percent or less of trading on the Irish Stock Exchange and the Borsa Italiana (European Securities Market Authority, 2014, p. 11). The point here is that approaching technological change through the lens of infrastructures invites IPE scholars to question how emergent technologies might change the form and extent of connections between different activities in different places, and unfold through the uneven spatiality of existing socio-technical systems.

The topological perspective on space implicit in the notion of infrastructures is thereby useful for unpacking the intersections between the 'global' or 'international' and 'national' or 'local' dimensions of technological change. Thinking about how infrastructures link together activities in different places or enable transactions across space and time in particular ways, we think, is a useful means of addressing the tendency in IPE to unreflexively operationalize the 'international' in terms of the activities of MNCs and multilateral regulatory agencies.

Bridging the technical and political

In Collier's (2011) very useful phrase, infrastructures 'bundle together' diverse sets of material devices and social relations intersecting at multiple levels of activity. Yet what roles do these relations themselves play in shaping infrastructures and shaping outcomes? Here, despite calls in STS in general and in SSF more specifically (Edwards et al., 2009, p. 372; Erturk et al., 2013), both literatures have been considerably less effective at explicitly addressing questions of distribution, power, and regulation. While fine-grained ethnographies of market practice and rich descriptions of particular devices are useful, they have rightly been criticized for lacking attention to dynamics of politics, power, and historical context. SSF have been critiqued for describing financial markets in manners that background discussions of power and legitimacy (Christiaens, 2016; Hardin & Rottinghaus, 2015, pp. 6–7). Self-critiques by SSF scholars have acknowledged how close empirical analyses of the inner workings of financial markets can lead to analysis that seems 'too cosy with finance' (Maurer 2012, p. 183), and at risk of 'losing sight of the more politicized function of markets' (Karlström 2014, pp. 25–26). This closeness has led some critics to observe that SSF can inadvertently replicate the understandings of market participants themselves about how finance and the economy more broadly work (see Fine, 2003). SSF have also tended to reflect rather narrow understandings of both the internal and external boundaries of high finance. Stress on trading rooms in major financial centers, for instance, has been criticized for overlooking the wider linkages of global finance with other sectors (Engelen & Konings, 2010; Ouma, 2016).

Yet strong critiques of STS tend to downplay the scope for productive interchange with IPE and related disciplines (but see Braun, 2016; Christophers, 2014;

Porter, 2013). In examining the ways in which the evolution of financial infrastructures transform, mediate, or ‘make durable’ existing forms of state and class power, IPE can provide the required attentiveness to those very forms of power themselves in order to supplement the descriptive and at times insufficiently critical nature of many SSF (Bryan, Martin, Montgomerie, & Williams, 2012, pp. 305–306). We think the concept of ‘infrastructures’ is of further use here.

The term ‘infrastructure’ itself, notably, can serve to invoke certain power relations (see Larkin, 2013). Indeed, IPE studies have at times harnessed notions of infrastructure in precisely such respect. Cerny (1994b), for instance, referred to global financial markets as the ‘infrastructure of the infrastructure’—pointing to the crucial role of financial markets in coordinating economic activity more broadly. IPE studies (e.g. Konings, 2010; Schwartz, 2015) have drawn on the work of Michael Mann (1984, p. 192) who traced how the ability of modern state to control the basic, backgrounded features of economic and social life since the nineteenth century notably included the development of official ‘[c]oinage, and weights and measures, allowing commodities to be exchanged under the ultimate guarantee of value by the state’. Braun (2018) makes a similar reference to the ways in which the ‘infrastructural power’ of finance—meaning the close entanglements between repo markets and the tools of contemporary central banking—has contributed to the post-crisis resilience of markets for securitization. In either case, infrastructures illustrate how the centrality of financial markets to the quotidian business of governance and economic activity confers degrees of power on financial markets and central banks, respectively. While the notion of ‘infrastructural power’ is a useful one, we think IPE studies treating global finance itself as infrastructure can benefit from the STS-inspired tracing of on-going constructions and operations of power in relations in and beyond financial markets themselves. There are two particular dimensions along which we think such relations can usefully be explored.

First, STS-inflected notions of infrastructures can further illuminate the changing links between financial markets and the ‘real’ economy of productive activity. Speculative financial markets, ultimately, depend on productive economies—the exact nature of this relationship has been raised a good deal in discussions of ‘financialization’ (Hall, 2013; Leyshon & Thrift, 2007; Mügge, 2009). Focusing on ‘infrastructures’ usefully complicates such narratives, highlighting the particular devices through which patterns of production and accumulation are translated into values and instruments amenable to speculation. Applications of HFT, as noted previously, often operate through efforts to predict movements in markets by processing digital signals of changes in underlying economic activities. Partially as a result of this, and because of their reliance on large, liquid markets with frequent trading activity, algorithms tend disproportionately to trade shares of large companies (EMSA, 2014; Goldstein et al., 2014). Or, put differently, HFT is dependent at least to some extent on the concentration of capital and corporate power in productive sectors as well as in financial activities. Fundamentally, then, it is worth asking how the construction of abstract and calculable asset streams amenable to speculative financial practices through financial infrastructures might still ultimately depend on particular configurations of productive activities. In short, what formations of labor and capital are needed to enable changing financial infrastructures to operate?

Second, the ways in which infrastructures remain wrapped up with patterns of governance and political authority can be productively traced through fine-grained analyses of power relations. Here it is worth recalling Susan Strange's nearly 30-year-old suggestion that opportunities to apply then-novel information and communications technologies to financial activities 'were opened up by a combination of conscious policy decisions by governments, especially on the regulation of financial markets and banking institutions, and by a production structure—itself, in turn, the creation of politically determined laws and administrative decisions—which was predominantly "capitalist"' (1990, p. 264). At a bare minimum, the adoption of new 'market devices' into existing infrastructures requires the passive acceptance of regulators, a condition that can be reversed. For all the hype about the ungovernable nature of algorithmic trading (e.g. Harris, 2011; Thompson, 2017), in practice HFT has been enabled by the creative interpretation of existing regulatory frameworks (Arnoldi, 2016), and shaped by ongoing regulatory debates about the definition and contents of algorithms (Coombs, 2016).

Infrastructures, equally, can confer, extend and *enable* new forms of governance. As recent studies of capital markets in both the Eurozone and the United States have recently chronicled (Braun & Hübner, 2018; Mattli, 2019), contemporary forms of hybrid public/private governance and corporate power often depend on control over key financial infrastructures. For instance, Roderick (2014) illustrates how a consumer data broker industry consisting of large and small fintech firms enhances and expands patterns of what Gill (1995) calls 'disciplinary neoliberalism' by enabling both the disciplinary character of states as well as the diffusion of marketized patterns of daily life. Gruin and Knaack (2019) similarly point to active state support for the development of fintech in China, which they argue is driven by the central government's ability to harness fintech applications to longer-standing development strategies. We see new modes of governance through infrastructures, albeit very different ones, at play with HFT too. The material articulations of HFT with existing trading systems have notably been shaped in part by regulatory debates about the appropriateness of various forms of automated trading. There have been continually contested efforts by public and private authorities alike to introduce both hardware and software 'speed bumps' that seek to discriminate in favor of liquidity 'making' algorithms and those that are 'taking' away liquidity (MacKenzie, 2018, pp. 516–518).

In short, then, STS-inflected notions of infrastructure can help illuminate three key sets of entanglements underlying technological change while bridging the respective strengths of two bodies of literature on global finance. A stress on the material manifestations of ideas in human practices and non-human objects helps to overcome the tendency in IPE to prioritize the ideational or the material separately. A topological perspective on space can also help overcome often artificial divides in IPE between different scales of 'global', 'national', and 'local' activities. Meanwhile, retaining the overt IPE stress on the political helps illuminate evolving forms of power and governance that can be lost in fine-grained analyses of 'technical' changes in financial markets. Table 1 below summarizes these points by identifying several key questions emanating from the complementary strengths that studying technological change through infrastructures can illuminate.

Table 1. Studying technological change through infrastructures.

| | |
|-------------|---|
| Materiality | <ul style="list-style-type: none"> - <i>What are infrastructures made of?</i> - (How) do infrastructures 'make durable' wider patterns of social relations? - How do new technologies 'plug in' to existing infrastructures? |
| Spatiality | <ul style="list-style-type: none"> - <i>What kinds of links do financial infrastructures facilitate between activities in different places and at different times?</i> - How and why do infrastructures vary across time and space? - How do infrastructures produce 'global' or 'national' financial markets? - What spaces can (and cannot) financial infrastructures reach? |
| Power | <ul style="list-style-type: none"> - <i>What kinds of social relations are 'bundled together' by financial infrastructures?</i> - How do infrastructures mediate the relationships between financial and 'real' economies? - How are financial infrastructures wrapped up with patterns of global governance? |

Scrutinizing fintech, inclusion, and stability: contributions to this issue

The articles in this collection investigate the emergence, establishment and limits of technological changes in global finance. Examining a range of different technologies and their associated financial practices through STS-inflected understandings of infrastructure injects badly needed nuance into two broad themes that correspond to the main hopes and fears expressed in optimistic and pessimistic accounts of 'the new financial sector' (Lin, 2014): inclusion and systemic stability. As suggested in the introduction above, these are important yet far from the sole themes emanating from utopian and dystopian visions of technological change. We thereby present this collection as an *initial avenue* for on-going dialogues between IPE and STS around questions of technological change in global finance and beyond.

Inclusion

Advocates of 'financial inclusion' tend to enthuse about the potential of technological changes for enabling greater access to credit (e.g. Hoder et al., 2016). In foregrounding the infrastructural character of emergent methods for standardizing complex and irregular patterns incomes, of mobilizing new forms of data to assess credit risks, and of new material and informational networks to facilitate payments, contributors to this collection bring out backgrounded politics and power dimensions that tend be overlooked in both critical scholarship and more supportive industry accounts.

Several authors consider the limits of 'fintech' for promoting inclusion, reflecting critically on the use of tropes around 'financialization' in emergent debates about fintech (e.g. Aitken, 2017; Gabor & Brooks, 2017). Langevin (this issue) scrutinizes the inability of Big Data applications in microcredit schemes to assess the potentially productive uses of micro-loans, noting how these efforts amplify pressures to repay growing debts. Bernards (this issue) points to the ways in which the promotion of novel forms of credit scoring through the use of psychometrics is closely bound up with the contradictory interactions of financial accumulation with concrete patterns of work and everyday livelihoods. However, changing infrastructures can also have some potentially empowering effects, albeit not always in the seemingly straightforward manners claimed by advocates of fintech. Rodima-Taylor and Grimes (this issue) point to a pluralization of technological infrastructures underlying remittance payment systems due the advent of mobile money and applications

of blockchain technologies. These changes, at times, enable migrants to exercise certain forms of agency and choice at the local level that have gradually improved everyday financial security.

Other contributions emphasize the ways in which fintech applications are inflected by the politically constructed character of discourses about 'financial inclusion' itself. Clarke (this issue) argues that the development of platform lending is dependent on a political context in which access to credit is increasingly understood and promoted as a necessary condition for wellbeing. Singh (this issue) draws on ethnographic data from Kenya and India to reveal how, *contra* the recent emphasis in development discourses on the possibilities for empowerment and 'participation' through technological change, actual engagements by the poor with new systems for payment and credits remain powerfully constrained by longstanding 'habits of authority'.

Systemic stability

Investigating technological change through STS-inflected understandings of infrastructures also provides valuable insights into the contingent stability of global financial markets. This is a particularly salient as some of the most widespread claims of advocates of 'fintech' revolve around the potential for emerging technologies to aid in developing more accurate, fine-grained, evaluations of risk, while critics decry how the increasingly pervasive and biased character of risk calculations contribute to rather than prevent longstanding instabilities. Contributors to this issue develop analyses of the interplay between regulatory reforms enacted in response to crises that have often catalyzed the development of new infrastructures for payments and risk management, and the development of new systemic risks. Campbell-Verduyn, Goguen and Porter (this issue) connect past and present expansions of information infrastructures underpinning risk management to the outbreak and trajectory of financial crises over a long-run cycle. Genito (this issue) reveals how changes in the socio-technical underpinnings of derivative market infrastructures in the aftermath of the global financial crisis, particularly the 'clearing mandate' requiring trades to be settled through central counterparty clearinghouses, poses important consequences for liquidity in times of crisis.

Future research directions

Technological change is a growing area of emphasis in popular and academic debates about global finance and the global political economy more generally. As we suggested at the outset of this article, numerous themes beyond financial stability and financial inclusion emanate from these and wider, much longer running debates on technology in IPE. The implications of technological changes for privacy and surveillance is one particularly important theme that we think can be further explored by studying infrastructures in manners that combine an IPE stress on politics with an STS emphasis on the intertwined nature of the material and ideational, as well as micro and macro levels of activity. As with other themes arising from discussions of technological change, bifurcated debates on the promises and perils of financial surveillance have largely taken place outside of IPE journals

(e.g. Amicelle, 2011; Glenn, 2014; Sadowski, 2019; Williams, 2009; exceptions include Kranke & Yarrow, 2018; Vlcek, 2012). These debates, we feel, can benefit from an injection of further nuance by foregrounding the wider financial infrastructures in which particular regulatory technologies ('regtech') are evolving.

The contributions to this special issue and the collection as a whole, in sum, offer pathways for what we think are wider opportunities for further productive engagements between IPE and STS, as well as IPE studies of finance and SSF. The complementary strengths of each can help advance debates on the sources and implications of technological change in finance and beyond. Echoing recent calls to elaborate avenues for 'translating' insights from STS perspectives while retaining the advantages of IPE and cognate disciplines (e.g. Best & Walters, 2013; Branch, 2018), this collection advances politicized notions of infrastructures in untangling the complex and continuous mixes of micro and macro, material and ideational, as well as technical and political underpinning of technological change in global finance. Our hope is that by avoiding any one-sided import and harnessing existing complementarities between these fields of study, interdisciplinary infrastructures can expand and facilitate more nuanced understandings of changes in finance and beyond.

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